U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 228

A Maritime Retrieval Program for Cloudy Satellite Temperature Retrievals Over the Northern Hemisphere Oceans

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MARCH 1981

This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

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1. Background

When cloudiness is sufficiently great, the NESS temperature retrieval methods rely heavily on the use of the four microwave radiances from the MSU instrument. These have broad vertical response functions with peaks located as follows:[1]

MSU_1	ground
MSU_2	600 mb
MSU_3	300 mb
MSU_4	90 mb

Over the ocean, MSU_1 is affected by the sea state and therefore carries little information about temperature in the lower atmosphere. This, plus the broadness of these channels, and their smaller number compared to the tropospheric infrared channels, implies a less accurate measurement of atmospheric temperatures below 100 mb than is obtained under clear conditions. This is especially critical in the extratropical parts of the Northern Hemisphere oceans because there all NESS retrieval coefficients are based primarily (~90%) on colocations with clear continental radiosondes. The result is a large seasonal bias in the mean error of NESS cloudy oceanic retrievals north of 30°N, large enough to increase significantly the error in retrieval temperatures (Phillips 1980). In summer, only about 20% of the oceanic retrievals are "microwave," but about 30% are so in winter.

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[1]The four stratospheric infrared channels constituting HIRS ($HIRS_1$, $HIRS_2$, $HIRS_3$, and $HIRS_{17}$) are also used as predictors in these circumstances.

In late 1979 it became apparent that the resources available to the NESS did not allow immediate development by NESS of a better colocation base for the oceanic cloudy retrievals in these latitudes. The author therefore began modifying his existing colocation system (Phillips, 1979)--which until then had been used merely to compare NESS temperature and precipitable water retrievals with radiosondes--so as to also obtain colocated brightness temperatures to produce regression equations for seven layer temperatures between 1000 and 100 mbs. For a single layer, these have the form:

$$T = C_1 + C_2 * \text{sea surface temperature} + \sum_{j=1}^{8} C_{j+2} * TB_j .$$

The 10 C's are statistically determined constants for a given layer, and the 8 TB_j are the 4 MSU brightness temperatures, plus those from the HIRS (infrared) channels 1, 2, 3, and 17. Application of this method to TIROS-N data in Nov 1979-Jan 1980 showed that it did indeed correct the undesirable aspects of the operational NESS cloudy method in these regions.

The new experimental system was then rewritten to be more efficient and reliable enough to qualify for operational use. In July 1980, NESS, through the NESS Sounding Steering Group, agreed that

1) NESS would use the NMC method for the third path oceanic retrievals in the latitude belt 30°N-65°N, for the reports put on the NMC/EDIS disk by NESS. Use of the same method would, subject to final approval, be also considered for the satellite reports sent by NESS on the GTS.
2) NMC would operate the special colocation base and make the retrieval coefficients and sea surface temperature field accessible to NESS.

It was first used on July 15 for the NOAA-6 satellite. (TIROS-N was still being reactivated at that time following the launch failure of its successor, NOAA-B.) Retrievals from TIROS-N were modified similarly beginning August 27.

Tables 1 and 2 summarize the comparative success of the NMC and NESS cloudy retrievals for TIROS-N during the 1979-80 winter, and for NOAA-6 during the last month in the summer of 1980 before implementation by NESS of the NMC method. The typical sample size is about 290 for the 44 winter days and 170 for the 32 summer days. Only "cloudy" colocations with $e < 150$ were used in these comparisons (See point i on page 7).

Table 1. Comparisons of (retrieval minus radiosonde) temperature differences from NESS method and from NMC method. Cloudy (3rd path) oceanic data 32°-66°N.

	Mean Difference		RMS Difference	
	NESS	NMC	NESS	NMC
	(A) TIROS-N Dec 8, 1979-Jan 20, 1980			
1000-850	-0.6°	-0.2°	3.6°	3.0°
850-700	1.0	0.2	2.7	2.5
700-500	1.0	-0.1	2.2	1.6
500-400	0.8	-0.2	2.6	2.3
400-300	0.7	0.1	2.3	2.3
300-200	0.7	0.5	2.0	2.2
200-100	-0.1	0.1	0.4	0.6
	(B) NOAA-6 June 11-July 12, 1980			
1000-850	5.9°	1.3°	6.7°	2.9°
850-700	1.2	0.1	2.3	1.7
700-500	-0.6	-0.0	1.6	1.4
500-400	-1.4	-0.4	2.2	1.6
400-300	-1.5	-0.0	2.6	1.8
300-200	-0.5	0.8	2.0	2.3
200-100	0.8	0.5	1.8	1.5
	NESS	NMC	NESS	NMC

Table 2. Comparison of (retrieval minus radiosonde) differences in height of pressure surfaces above 1000 mb surface from NESS method and from NMC method. Cloudy oceanic data 32°-66°N.

	Mean Difference		RMS Difference	
	NESS	NMC	NESS	NMC
(A) TIROS-N Dec. 8, 1979-Jan 20, 1980				
850	3 m	1 m	17 m	14 m
700	10	2	24	22
500	20	-0	33	26
400	21	-5	37	26
300	25	4	46	33
200	33	24	55	40
100	- 7	7	52	40
(B) NOAA-6 June 11-July 12, 1980				
850	28 m	6 m	32 m	14 m
700	35	7	42	20
500	29	8	40	26
400	19	5	36	28
300	8	5	38	33
200	1	14	44	42
100	16	23	54	48
	NESS	NMC	NESS	NMC

This Office Note describes the operational and meteorological details of the program developed at NMC. Like the NESS system, it handles two satellites. It differs from the NESS method in several ways, however.

a. Only Northern Hemisphere (30°-66°N) maritime colocations are used in the colocation base from which statistical regression coefficients are obtained.

b. The spatial mismatch between a column of radiance measurements and the radiosonde is minimized by horizontal analysis (interpolation) of brightness and retrieval temperatures to the radiosonde location from a collection of individual NESS retrievals from one orbit within 600 km of the station. (As in the NESS system, radiosonde temperatures are interpolated in time to match the time of the satellite observation.)

c. Cloudy or partly cloudy ("N*") colocations are the dominant component of the colocation base.

d. The NESS statistical system uses a reduced set of orthogonal eigenvectors of brightness temperatures as "predictors." NESS also uses a reduced set of orthogonal eigenvectors of temperatures at 40 levels as predictands, from which the seven values of layer mean tropospheric virtual temperatures (1000-850, 850-700, 700-500, 500-400, 400-300, 300-200, 200-100 mb) are finally derived for the data given to NMC.[2] In the NMC system the regression is directly from the selected predictors to each of the seven layer virtual temperatures.

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[2]NESS data sent on the WMO's GTS has a slightly different distribution of vertical points between 300 and 100 mbs. In both types of reports, NESS converts from real to virtual temperatures, using measured or climatological humidities, for the final output.

e. The NMC system uses sea surface temperature as an additional predictor when it is judged statistically useful for a given layer.

f. The horizontal analysis feature described under b above results in a more aggressive colocation system (about 1/2 to 1 useful colocation per station per day).

g. Geopotential heights at the standard surfaces (1000, 850, etc.) are used to define the radiosonde mean layer virtual temperature in the NMC system. The automatic quality flagging procedures on these seem to be more reliable than for the individual temperatures in a radiosonde report that are used by NESS.

h. In the NMC system an opportunity is presented, before an accumulation of colocations is used to update retrieval coefficients, to eliminate significant radiosonde errors that may have slipped by the quality flagging procedure in the automatic NMC data processing.

i. All NESS retrieval types (clear, N_*, or microwave) are used in the analysis to radiosonde locations described in b above. In order to retain a measure of the retrieval process, a number $\underline{e}$ is assigned to each original retrieval

$\underline{e}$ = 100	Microwave + HIRS'
$\underline{e}$ = 200	N_*
$\underline{e}$ = 300	clear column

and $\underline{e}$ is then also analyzed to the station location, for later reference in processing this colocated column of satellite retrieval temperature and brightness temperature. Only colocations with e less than or equal to a critical value

IEC

are saved.[3]

2. Outline of procedure

The system uses a disk data set NWS.NMC.PROD.SAT3PATH containing 229 records of 1200 bytes each. A back-up data set NWS.NMC.BKUP.SAT3PATH is also used. A third data set of 29 records, NWS.NMC.PROD.S3PRETRV, contains a copy of records 1 and 202-229, for use by NESS. All disk data is in integer format. Reference is made to it twice/day (when the basic colocation program is run) and when new retrieval coefficients are generated at "update time."

Record	Use	Information
1	Always	System parameters and current NMC retrieval coefficients.
2-41	Always	Up to 40 successive records of 12 hrly (00 and 12 GCT) raob data, each record containing up to 20 selected Northern Hemisphere maritime stations.
42-81	Always	Up to 40 successive records each containing up to 20 colocations of satellite data analyzed to the radiosonde locations. These use "NESS" retrieval temperatures.
82-121	Always	Ditto, where "NESS" microwave retrievals have been replaced by "NMC" retrievals before being analyzed to the radiosonde location.
122-161	Update	Up to 40 records ("pair records") each containing up to 20 colocation events formed by matching NESS satellite data from records 42-81 with radiosondes from records 2-41 (interpolated in time).
162-201	Update	Ditto, using 82-121 (NMC) instead of 42-81 (NESS).
202-229	2/day	The latest NMC sea sfc temperature field for the Northern Hemisphere, obtained from the 0000 GES field.

[3]At present IEC=200. A smaller value IEV=150 is presently used to define the very cloudy events that are used in verifying the accuracy of microwave retrievals. The slightly relaxed limit for the colocation base is believed to improve the size (and statistical reliability) of the base without degrading the meteorological content.

The parallelism between (42-81 plus 122-161) for NESS retrievals and (82-121 plus 162-201) for NMC retrievals is present because originally it was used to demonstrate the value of the NMC method over the then operational NESS method. When NESS uses the NMC method, the results should be identical, except for a very minor effect caused by the fact that NESS will use the NMC method at the time a retrieval is put on the NMC/EDIS disk by NESS, whereas the NMC 2/day colocation program will be recomputing the microwave retrievals from the brightness temperatures on the NMC/EDIS disk about 8-20 hours later.[4] This time difference means that the two systems will occasionally differ briefly on whether the newest or the previous NMC retrieval coefficients are used immediately after their update. The parallelism on the disk is worth preserving however as a useful check on the proper functioning of both systems, and as a future testing option if NESS develops its own improved oceanic microwave retrieval system.

There are five code packages involved:

I. Code to initialize the disk with station numbers, satellite numbers, and other status and processing parameters.

II. Colocation code to be run twice per day, preferably between the last "FINAL" ADP data dump at NMC and the first ensuing data dump for the next 12-hour file. This choice of run time of ≈1000 and 2200 GCT maximizes the ability of the 2/day code to capture raobs and satellite data that

[4]The 2/day NMC colocation program gets 1200 GCT raobs (for example) at about 2200 GCT, in order to allow maximum time for data receipt. At that time, it makes satellite colocations for the preceding 12-hr period 00-12 GCT, so that the slightly variable positions of the "fixed" ship radiosondes can be adjusted for when analyzing satellite data to the ship location that is valid for the time of satellite passage. This processing delay also enables late satellite data to be considered.

have been captured 12 hours earlier when that earlier run might have been aborted. This code puts the station raobs for this time in the proper record 2, 3, ..., 41. It also puts colocated satellite data in records 42-81 and 82-121. A preliminary job step in the 2200 GCT run puts the sea surface temperature field onto records 202-229 from the 0000 GES file.

III. Pairing code. This is called in automatically by II every NUP days.[5] It pairs up each colocated satellite report in the previous NUP days that has been collected on records 42-121 with the time interpreted raob data from records 2-41. The pairs are written into the record groups 122-161 (or 162-201) in rough chronological order, with the obvious discarding of the oldest pair records in 122-161 (162-201) when necessary to make room for the new batch. This code also relocates the latest unused 2/day raob and satellite data on records 2-121 to begin the next colocation collection period of NUP days, and reinitializes the relevant status parameters in record 1. The pairing code also prints out the relevant raob and satellite data whenever the colocated NESS retrieved temperatures differ from the raob temperatures by more than 7 degrees. This allows inspection of the raobs for possible errors.

IV. The Update Code. This code is run over the counter as soon as the manual inspection just described has determined whether any raobs are suspect. It first reads in editing cards which (if present) instruct it to delete any erroneous raob temperatures from the pairs in records 122-201. It next compares the success of the very cloudy retrievals ($e < IEV$, see footnote at end of section 1) for the NESS and NMC pairs collected by the just previously run pair code (e.g., the past 7 days).

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[5]Presently every 7 days.

This is done for each of two satellites. It then takes the most recent NESS pairs, for each satellite, up to a total number at least equal to a parameter ICOLRQ in record 1 (presently = 100) and, by least squares regression, generates new retrieval coefficients for that satellite. The choice of which of the nine predictors to use for each of the seven layers for each of the two satellites is set by data cards.[6] An evaluation of the success of the new coefficients on this dependent data set is made, and the new coefficients (together with a record of the colocation data period) are written onto record 1.

V. A special routine ("NMC3PT") for NESS to convert conventional NESS microwave oceanic retrievals in the area 30°N-65°N, 110W-120E (Pacific) or 10E-80W (Atlantic) for insertion on the NMC/EDIS disk. It uses the current NMC retrieval coefficients in record 1 and the ocean temperatures in records 202-229. An equivalent program "GTS3PT" exists for the NESS "Satem" reports for the GTS. Both are for use by NESS, not NMC.

Codes II and III were made part of the NMC operational job stream on September 10, 1980. They are run in the "must run" part of the final cycle.

Approx. Run Time	Job Name	Code
2200 GCT	WW0812W3	II (including new SST field)
1000 GCT	WW0812K3	II (no SST)

Code III is called ("IJP") by one of these every 7 days with job name WW1S3PZ3.

[6]This selection is made by a one-time advance "screening" to find, for each layer, the best predictors which are also reliable on independent data. Choices so far have been made using Nov 1979-Jan 1980 TIROS-N data, (a) for the full complement of four MSU and four HIRS channels, and (b) for the case of a missing MSU_3.

3. Initialization Code and Record 1

The 300 I*4 integer words in record 1 contain the following parameters:

Word	Parameter	Value, etc.
1	Activation Flag	= 12345: 2/day program will run. ≠ 12345: 2/day program will stop.
2	t_{RAOB} (seconds)	time (in seconds since begng of 1979) of the latest raob collection already in records 2-41.
3	t_{SAT} (seconds)	ditto for beginning time of last 12 hr sat. colocs in records 42-121 (Normally this equals t_{RAOB}-43200.)
4	NSTN	number of radiosonde stations (L.T.E. 20)
5	ISATA	Ident number for satellite A (e.g., 2 for NOAA-6)
6	ISATB	Ident number for satellite B (e.g., 1 for TIROS-N)

Note: Neither of these should be zero. If only one satellite is active, set the missing ident to 7777.

Word	Parameter	Value, etc.
7	τ	time (in units of 12 hours since bgng of 1979) for raob collections in record 2.
8	NR_{NESS}	record number (42-81) for next NESS colocation reports
9	NR_{NMC}	ditto (82-121) for NMC.
10	NUP	number of days between calling of pair code (now = 7) to begin coefficient update.
11-16	-	(yr, mon, day; yr, mon, day) defining colocation base for current retrieval coeffs located in KCOF for satellite ISATA. Zero if no coeffs.
17-22	-	Ditto for satellite ISATB.
23	SCAN (km)	Collection radius (now 600) within which original retrievals are collected from 1 orbit passing a radiosonde station.
24	WINDOW (km)	(Now 50) Distance from station within which a single retrieval is enough to justify a colocation.

Word	Parameter	Value, etc.
25	ANAT (.1 deg)	(Now = .5 degree) Acceptable analysis (or interpolation) error allowed in analyzing satellite temperatures to raob location.
26	IEV	e value (retrieval path parameter) defining cutoff above which colocations are not used in accuracy assessment by update code. Now set at 150.
27	IEC	e value above which colocations are not used in colocation base and therefore not saved in records 42-121. Now set at 200.
28	ICOLRQ	Number of colocations required to form a colocation data base for update code. Now set at 100.
29-30	-	First and last record number of the NESS pairs put into records 121-161 by the last running of the pair code (i.e., this identifies the most recent NESS pair records). (They are used by update code in its verification assessment and to start the coefficient update base.) Zero means no pairs on disk yet.
31-32	-	Ditto for the NMC pair records in 162-201.
33-55	-	Zeros (unused)
56-75	KWMO (20)	20 words for WMO radiosonde station numbers (used in collecting raobs by the 2/day code). The first five stations are ships.
76-95	KLAT (20)	20 words for latitude (in .01 degrees) of raob stations. (Ship lat's are the WMO assigned latitude.)
96-115	KLON (20)	Ditto for station longitude.
116-160	KSHP (3,3,5)	3 most recent times, lat and long observed for the 5 ships. (Updated as raobs are collected.)
161-300	KCOF (10,7,2)	Latest retrieval coefficients ($*10^4$) for (constant + 9 predictors), 7 layers, and for satellites A and B.

Time is usually counted in seconds since the beginning of 1979. Subroutines

TIMCAL (IT,ICAL)

CALTIM (ICAL,IT)

INTEGER*4 IT,ICAL(6)

are used to convert time (in seconds since beginning of 1979) into a six figure date time group (in ICAL(6): yr of century, mon, day, hr, min, sec) or vice versa. They will work for 1979 through 1998 with automatic recognition of leap year, etc. A time parameter, ITAU = number of 12-hr intervals since beginning of 1979, is sometimes used for decisions based on 12 hourly periods. (Note word 7 in the list above.)

The initialization code sets up the entire disk area (except the sea sfc. temp. in records 202-229), using data cards as input. <u>The following listing assumes NSTN in word 3 is equal to 10</u>, as an example.

Data Card	Format	Meaning and place in 1st disk record
1	I10	Activation Flag for word 1
2	2I10	Satellite ident for words 5 and 6
3	I10	Number of raob stns (word 4,NSTN)
4-13	3I10	WMO number, lat and long (.01 deg) for each station (words 56-115) West longitudes are negative (0 to -17999)
14	I10	NUP (word 10). Should be L.T.E. 18.
15	I10	SCAN (km, word 23)
16	I10	WINDOW (km, word 24)
17	I10	ANAT (word 25)
18	I10	IEV (word 26)
19	I10	IEC (word 27)

Data Card	Format	Meaning and place in 1st disk record
20	I10	ICOLRQ (word 28)
21	6I5	a) If 1st number L.T. zero, existing coefficients in KCOF (i,j,1) for satellite A will not be changed. Ditto for words 11-16.
		b) If 1st number = 0, existing coeffs in KCOF (i,j,1) and words 11-16 will be made zero (i.e., unavailable).
		c) If 1st number G.T. zero, the 6 numbers will be interpreted as the time base (words 11-16) for the retrieval coefficients that now follow on the next 14 cards. (Under options a or b, these 14 cards are not present.)
22	5F10.4	1st 5 of 10 coeffs for layer 1.
23	5F10.4	2nd 5 of 10 coeffs for layer 1
24-35	5F10.4	Etc. for layers 2-7.
36 and 37-50		Repeat of 21-35 for satellite B.
51	6I5	Yr, mon, day, hr (0 or 12), min (0), sec (0) for 1st raob collection to be obtained by next run of 1/day code.
		(a) If (yr) L.T.E. zero, existing raob and satellite reports on disk records 2-121 will be left alone, and words 2,3,7,8,9 plus KSHP in record 1 will not be changed.
		(b) If (yr) G.T. zero, existing raob and satellite data in records 2-121 will be erased, and initial values will be assigned for words 2,3,7,8,9 plus KSHP in record 1.
52	I10	"IPRNU"
		(a) If L.T.E. zero, all old pairs in records 122-201 will be erased and words 29-32 changed to zero.
		(b) If IPRNU greater than zero, existing pair records in 122-201 and words 29-32 in record 1 will be left as is.

The options available in data cards 21, 36, 51, and 52 (as listed above) give considerable flexibility in changing the system parameters, and a special run of the initialization code with proper data cards will take care of most desired system changes.

A. Add a new station. This can be handled simply by an ad hoc "on the fly" change of the following words in record 1:

(1) Increase NSTN in word 4 by 1.

(2) Insert WMO id, lat and long (in .01 deg) in first available words in KWMO, KLAT, KLON.

B. Delete a station. A similar ad hoc change is possible here, too. Change its WMO number, lat and long in KWMO, KLAT, and KLON to zero. Do not change NSTN unless it is the NSTN-th station that is to be deleted.

Either one of the above two changes can also be handled by a complete run of the initialization code with changes made to data card 3 (NSTN) and a change to the individual station cards as described under A and B above. Data cards 21 and 36 should be negative (to retain retrieval coeffs), data card 51 should be negative (to retain existing colocations--which are valid under the limited station change type A or B above), and the last data card should be greater than zero to retain all pairs.

C. A redefinition of stations (in which, for example, station #11 is changed to a different WMO ident, lat and long). This requires a restart of the 2/day colocation system, with revised data cards (NSTN), and ff. Data cards 21 and 36 (or their equivalent) should be negative to save retrieval coefficients. The penultimate data card (51 as listed above) should have a definite 12-hourly date time group to initiate new raob and satellite colocations. The last data card (IPRNU) would normally be chosen greater than zero so that existing pair records are saved.

D. Change of satellite. This does not require a restart of the raob/sat collections. If, for example, satellite B were being replaced by a new satellite, the following run of the input code would handle matters completely:

1) The second word on data card 2 would be changed to the new satellite number (for ISATB in word 6, record 1).

2) Data card 21 (in the above sample list) would have a negative first integer (so as to save coefficients for satellite A).

3) Cards 22-35 of course would be deleted.

4) The new data card 22 (card 36 in the above sample list) would have zero for its first integer to erase coefficients for the superseded satellite B.

5) It would be followed by the 6I5 card. This can be zero since any data on the disk for the superseded satellite B will be ignored by all codes as soon as ISATB is changed in word 6 on the disk.

6) IPRNU in the last data card should be positive, so that pairs for satellite A are not lost. (Pairs for old satellite B will be ignored and eventually disappear.)

The only other major system change is that caused by a change in the operational status (off to on, or vice versa) of one of the eight radiance channels used for "microwave" retrievals. This affects only the UPDATE code.

4. The 2/day colocation program

A. Job structure

This program is run twice/day 1000 and 2200 GCT in the "must run" beginning portion of the final cycle. It has three steps at 2200, but step I is omitted at 1000 GCT.

Step I. Put the Northern Hemisphere sea surface temperature from the 00Z NMC "GES" file--a 46 x 181 word array for a 2x2 degree lat.-long. grid onto records 202-229. This GES file data source is updated every other day at NMC (just prior to this step). The step I code converts the temperature (°K) to integers after multiplying by 1000, before writing records 202-229. The first four words in record 202 contain the yr (of century), mon, day, and hour associated with the GES file. Words 5-300 in record 202, words 1-300 in records 203-228, and words 1-230 in record 229 contain the integer values of 1000 x SST in sequential order ((SST(i,j), i=1, 181), j=1,46). The last 70 words of record 229 are zero. All SST values are first checked to satisfy the range 265°<SST<308°. Violation of this range at any point will prevent the writing of records 202-229, but with a warning message printed out. This feature prevents the replacement of the quite useful field already on records 202-229 with corrupted data in case of disk failure, etc. The same 28 records of SST are written to records 2-29 of data set NWS.NMC.PROD.S3PRETRV for use by NESS.

Step II. This is the primary colocation code that collects radiosonde and satellite reports. The details of how it does this are described below. It stops with a condition code of 1 when enough data has been collected (NUP days = word 10 in record 1) to call the pair code of Step III. Until then it stops with a zero condition code.

Step III. This is the pairing code. It is run automatically only when Step II has stopped with a condition code of 1. The details of the pairing code are described in section 5.

The colocation code of Step II uses a main code and the following subroutines

RADIO	Collect raobs from the proper ADPUPA file, convert to layer values of T and water[1] and write this data as one record in the proper sequence of records 2-41.
SATCOL	Collects NESS retrievals from the NMC/EDIS disk 12-hour period ending with the latest raob set gathered by subroutine RADIO, and organizes them into colocation events at one of the selected radiosonde locations.
TIMCAL CALTIM	The time conversion routines described in section 3.
W3AQ06	NMC library routines to get current time

(SATCOL uses additional subroutines described below)

B. The primary colocation main code. This does the following tasks:

(1) Print out current time (GCT)

(2) Read in record 1. If word (1) = 12345, proceed. If not, go to stop procedure.

(3) Print out (see section 3) KPAR and the station latitudes and longitudes. Put KWMO, KSHP and other parameters from record 1 into COMMON (for access by RADIO and SATCOL), Put rescaled decimal form of retrieval coefficients from KCOF into array COF.

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[1]RADIO and SATCOL still contain vestiges of their original format when they were used to simply assess the accuracy of satellite retrievals of 15 layer-temperatures from 1000 to 0.4 mbs and precipitable water in the 3 layers 1000-700, 700-500, and 500-300 mb.

(4) Determine time (t) value for the latest raob set in records 2-41 and for each of the two raob sets on the ADPUPA 00Z and 12Z files.

(a) If the older of the ADP has not been obtained yet, call RADIO to get this raob collection.

(b) If the newer ADP raob file is at least 9 hours old, call RADIO to also get the second ADP raob set.

(c) After each return from RADIO, the ship locations are updated in COMMON for later access by SATCOL.

(d) On the final return from RADIO, update word 2 in record 1 (see section 3) and the array KSHP. Then write this updated record 1 onto the colocation disk. RADIO having already written the raobs to the disk, this immediate updating of the disk record 1 insulates the disk data from possible system aborts occurring before the primary colocation code has completed.

(5) Call subroutine SATCOL as many times as needed to get 12-hourly batches of colocations. The first one begins with the 12-hour period from t_1 = (word (3) in record 1 + 43200) through

t_2 = (word (3) in record 1 + 86400).

These calls are repeated until t_1 would equal the time of the latest raob collection that has been obtained by RADIO (word 2).

After each call, words 3, 8, and 9 in record 1 are updated and the revised record 1 is written to the disk.[2]

(6) Before stopping, the program does a print-out of record 1, a summary of raobs present in records 2-41, and the latest group of satellite colocations.

(7) The normal stop is a zero condition

STOP

However, as soon as there are (NUP+1) x 2 raob collections in records 2-41, the stop is condition one:

STOP 1,

so that the pairing code will be called in.

C. Subroutine RADIO

This subroutine collects raobs from the ADPUPA file to which it is directed by the main code (via the FT number MDRS in COMMON). For each station it forms a 30 I*2 word array simulating the type of data given in a satellite retrieval:

Word	
1	Station number (1 - NSTN)
2	Latitude in 0.01 deg
3	Longitude in 0.01 deg.

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[2]The actual operation of writing record 1 to the disk here and at the end of RADIO is the only moment when a sudden computer stoppage could interfere with complete automatic recovery in a restart or in the next 2/day operation. Other than this, the only machine sensitivity is that of unrecognized hardware errors (e.g., writing in wrong record because of malfunction), or a complete disk failure. These are protected against in the form of a back-up data set described in section 5.

Word	
4	t_1 (time = 32768*t_1 + t_2)
5	t_2
6-20	Mean virtual temperatures for 15 layers between 1000, 850, 700, 500, 400, 300, 200, 100, 70, 50, 30, 10, 5, 2, 1, and 0.4 mbs, in 0.1°K, as available.
21-23	Precipitable water (in mm) for layers sfc-850, 850-500, 500-300 mb, as available.
24	Sum of 21-23 (Total precipitable water)
25	Surface T in 0.1°K
26	Sea surface T in 0.1°K
27-29	"Missing" 7777
30	Surface pressure in 0.1 mb.

(No use is made in the other parts of the present colocation system of words 13-25 and 30.) Each raob that is successfully captured from the WMO station number list in KWMO, with station number n=1 thru NSTN, has its 60-byte array entered into the n-th successive block of 60 bytes in a 300 I*4 array in core. Stations which were unavailable (or garbled) are filled in with a 30 I*2 array of 7777, as are the arrays for the unused stations NSTN+1, NSTN+2,...., 20. Missing data in part of an array is replaced by 7777.

Both mandatory and significant level data are extracted from the station report (see NMC Office Note 29). The radiosonde "raw" data, including NMC quality control flags, is printed for each station. The final "pseudo-satellite" radiosonde report described above is also printed. Geopotential heights at mandatory pressure levels are used to obtain layer virtual temperatures for as many of the previously described "satellite" layers as possible. Reported temperatures and dewpoint depressions (including significant levels) are used to construct precipitable water in three layers. NMC quality control flags are used to determine the "goodness" of the data.

Some further details of RADIO are:

(1) Permanent ships which are off location by more than 1° latitude or longitude are classified as moving ships by NMC. In searching for the five permanent ships, RADIO will look at moving ships too. Any permanent ship off location more than 2.5° latitude and (or) 4.0° longitude is considered missing.

(2) Geopotential heights are accepted as "good" data when the quality control flags are:

A or I = passed NMC vertical consistency check with tight limits

H = manual HOLD inserted by Aviation Branch

Temperatures (for use in computing precipitable water) are accepted when flagged A, I, or H.

(3) The first significant level has no quality flags and is accepted as the earth's surface.

(4) Heights and temperatures must have <u>at least</u> one "good" vertically adjacent neighbor (i.e., neither missing nor flagged as bad data), otherwise they are not accepted.

(5) Gross Error Checks:

Reported temperatures and computed thickness temperatures are considered as bad data if they are outside the range -100°C to +50°C.

Dewpoint depressions greater than 40 degrees are not accepted. Depressions between 30 and 40 degrees are considered "motor-boating" values--a relative humidity of 15% is assumed.

(6) Specific humidity is computed at each temperature level and the profile is vertically sorted according to pressure. Precipitable water is then computed in each radiosonde layer. The precipitable water sounding must cover the layers surface-700 mb and 700-500 mb (within 20 mb of the boundary pressure) in order to be valid. The 500-300 mb layer must at least have data up to 400 mb.

(7) Total precipitable water in the column surface-300 mb is stored in word (24) only if all three sub-layers have good data.

(8) A list of the missing radiosonde stations is printed at the completion of RADIO.

(9) Missing or suspect data is recorded as 7777.

(10) The sea surface temperature in word 20 is obtained by horizontal interpolation from the SST field in records 202-229 by the subroutine GETSST.

D. Subroutine SATCOL

This routine produces one or more 1200-byte records containing up to 20 colocated satellite retrievals at the location of the NSTN stations from a 12-hour time period. Data from each of two satellites is treated separately (not combined). The format of a successful colocation is a 30 I*2 word:

Word	
1	Station number (1-NSTN)
2	Latitude (.01 dg)
3	Longitude (.01 dg)
4	t_1 time = $32768{*}t_1+t_2$
5	t_2
6-12	Retrieved layer mean temperatures for 7 layers defined by 1000, 850, 700, 500, 400, 300, 200 and 100 mbs (in 0.1°K)
13-20	8 brightness temperatures (in deg K/64) for MSU channels 1-4, HIRS (1-3) and HIRS 17.
21-27	Unused (=7777)
28	e (NESS retrieval path; see section 1)
29	Unused (= 7777)
30	Satellite ident number (e.g., TIROS-N = 1, etc.)

These 60-byte arrays are inserted sequentially into a 1200-byte core array which, when full, or when all relevant retrievals in this 12-hr period have been considered, is written to the disk sequentially as one of the records 42-81 or 82-121. (Empty words = 7777)

SATCOL uses the following subroutines

W3FI40 — NMC library routine to get 140 I*2 word satellite retrievals from the NMC/EDIS disk[3]

CALTIM and TIMCAL — (See section 1)

NEW3 — To convert a NESS microwave (3rd path) oceanic retrieval to an NMC retrieval using array COF

ANAL — To analyze, to the raob location, satellite retrieved temps, brightness temps, and retrieval path "e" from the colocation batch obtained from one orbital pass by a satellite near a station.

ITSOL — A routine used by ANAL to obtain analysis weights by inverting the analysis matrix.

GETSST — To get sea surface temperature at location of a 3rd path retrieval so that NEW3 can produce NMC values of retrieved temperature.

Subroutine SATCOL operates as follows:

(1) Given the initial time t_o in seconds of the desired 12-hourly collection interval, an outer loop uses W3FI40 to search for retrievals within SCAN km of each of the stations. This search is done three times; first for a short period Δt of about 200 seconds preceding t_o, then for the 12 hours following t_o, and finally for the period of Δt seconds after (t_o + 12 hours). The first and third of these intervals allow retrievals to be captured as an entire group from an orbit that passes a station very close to 0000 or 1200 GMT.

The locations used for the five ships in the first and third search are those reported for the radiosondes at the beginning and end, respectively,

[3]The format of these reports is described in the NESS memo "for the record" by L. Hyatt, entitled "Finalization of the NMC/EDIS File Formats for TOVS Data," dated May 10, 1978.

of the central 12-hour collection period. For the central 12-hour search, the average location of the ships at the two end points is used. If a ship radiosonde was missed, the standard location is used.

(2) A retrieval in these time ranges is saved, up to a maximum of 40 per station, if

a. it is within SCAN kms of the station

b. it comes from an acceptable satellite number ISATA or ISATB

c. at least one retrieved temperature below 100 mb is present.

Individual retrievals are saved in the condensed 30 I*2 format described earlier (except that temporarily e has the value 1, 2, 3 instead of 100, 200, 300).

(3) After completion of (1) and (2), the retrievals collected for a particular station are organized sequentially according to time of observation. Up to a maximum of four colocation events are then determined for each station. This is done by noting points in the chronological sequence at which the retrieval time increases by an amount slightly greater than twice the time required for the satellite to traverse a distance equal to the collection radius, SCAN. This results for a given station, in an ordering of its nearby retrievals into 1,2,3, or 4 batches, each batch consisting of data taken from one orbit of one satellite near the station. (A batch is dropped if all of its retrievals lie just outside the center 12-hour period, in order to avoid duplication of colocations from the previous or next run of this program.) This time separation between colocations also serves to ensure that only one satellite is involved in each colocation batch.

(4) For each station, separately for each of its colocation batches, the 7 values of retrieved temperature, the 8 brightness temperatures, and the e value (now multiplied by 100) are analyzed to the station location by ANAL. The single 30 I*2 report from this batch is composed of these analyzed values (t being set equal to the average value of t from individual reports), and it this report that finally is written to the disk.

(5) The horizontal coordinates x and y with respect to the radiosonde station for each retrieval in a batch presented to ANAL for analysis is expressed by SATCOL in thousands of kilometers, using an approximation to a local stereographic Cartesian projection centered at the station:

$$x = 6.371\ \lambda(\cos\theta_o - s\ \sin\theta_o)$$

$$y = 6.371\ \ (s + 0.5\ \lambda^2\ \cos\theta_o\ \sin\theta_o)$$

in which

θ_o = station latitude

s, λ = difference in latitude and longitude (radians) between satellite report and station.

Subroutine ANAL is given the data, for each of the 16 variables in turn, expressed as deviations from the mean value of the reports for that variable. An analyzed value is returned only if

a. There is a report in all four quadrants (first considering quadrants oriented according to the x,y axes or, if this fails, using axes at 45°).

b. Failing a, at least one point is closer than the distance set by WINDOW.

The analysis of the deviations to the origin (station location) of the deviation is based on optimum interpolation principles (assuming no error), using a simple Gaussian correlation function

$$r_{ij} = \exp\,(-2d^2)$$

where d is the distance between points i and j in thousands of kilometers. (This correlation function was found to reproduce quite well the results from several subjective hand analyses of satellite data.) The subroutine ITSOL developed by K. Bergman is used to invert the optimum interpolation correlation matrix. It returns a normalized estimate of the interpolation error, which, when unnormalized by multiplication with the standard deviation of the data, is used by SATCOL as a test. If this value is larger than that set by ANAT, the analyzed value is discarded (≡7777) by SATCOL. (The analyzed e value is always accepted of course.)

(6) SATCOL prints out for each station a 30-word copy of the individual retrievals saved in step (2) above, and a copy of the final reconstructed retrievals accepted as valid at the station locations. <u>These, together with the individual radiosonde records printed out by RADIO</u>, must be referred to in judging whether any large radiosonde-satellite discrepancies uncovered by the pair code are due to erroneous radiosonde data and therefore should be ignored (edited out) by the update code.

(7) After steps (4-6) are done with the original NESS retrievals from one colocation batch, the process is repeated after any 3rd path "microwave" retrievals in that batch have had their retrieved temperatures replaced by values determined by the NMC method in subroutine NEW3.

(8) Subroutine NEW3 takes an original 3rd path (microwave) NESS retrieval (in the format described under subsection D above) and using the retrieval coefficients in COF(10,7,2) computes an NMC retrieval. For k=1-7, and n=1,2 (one of two satellites), the procedure is

$$T_k(\mathrm{NMC}) = \mathrm{COF}(1,k,n) + \mathrm{COF}(2,k,n)*\mathrm{SST} + \sum_{\ell=1}^{8} \mathrm{COF}(\ell+2,k,n)*\mathrm{TB}_\ell$$

where

T_k is in °K,

SST = sea surface temperature (°K)

TB_ℓ = brightness temp (in °K) from words 13-20 in the condensed original retrieval array.

The sea surface temperature is obtained from GETSST (which accesses records 202-229). A MSG (=7777) is given for T_k by NEW3 if a needed brightness temperature is missing and a warning is printed. No conversion to NMC values is made if all 7 NESS retrieved temperatures are missing.[4]

(9) Colocated satellite reports for all stations, separately for NESS and NMC retrievals, are collected in a 1200-byte record for writing to the disk sequentially in records 42-81 (NESS) and 82-121 (NMC). Colocated reports having an analyzed e value greater than IEC are discarded before they would be included in the 1200-byte record that goes to the disk. Colocations in the 1200-byte record written to disk are not ordered according to satellite identification. (They are ordered in station sequence, however.)

---

[4]A 4th retrieval "path," in which only temperatures above 100 mb are produced, is occasionally produced by NESS (presumably when microwave radiances are unusable).

(10) Separate 1200-byte output arrays are used for NESS and for NMC colocated retrievals. Each goes to its proper location on the disk--records 42-81 for NESS, 82-121 for NMC.

(11) The times recorded in words 4 and 5 is the average time of original retrievals in the colocation batch.

5. <u>The pairing code</u>

The pairing code does the tasks described on page 10 after the MAIN colocation part of the 2/day program recognizes that there are now 2(NUP+1) 12-hrly raob collections in records 2-41. (NUP in word 10 of record 1 on the disk is the number of days between updating of coefficients. The extra 1 day is to get the raob collection at the end of NUP days and to allow for the possibility that this was obtained in a delayed run.) The tasks are performed as follows.

A. Copy the full 229 records on the disk to an identical data set NWS.NMC.BKUP.SAT3PATH on a different operational disk pack. This second data set is the <u>back-up</u> data set. Although not written on or read by the colocation part of the 2/day code, this data set is available in case

(1) The normal disk pack is damaged

(2) Machine malfunction (or operator abort) interferes with the writing of disk records on the normal disk data set.

(3) There have been unforeseen problems in the following update code (see section 6).

B. Print the current time and the current contents of the first 55 words of the first record (see page 12).

C. Count the number of pair records for NESS pairs (in 122-161) and NMC pairs (in 162-201) that are already on the data set. Establish the time limits for which satellite reports are to be matched with raob data $t_1 \leq t \leq t_2$:

t_1 = beginning of period (= time of raob collection in record 2)

$t_2 = t_1 + 86400*NUP$

The following steps D, E, and F are done first for the NESS colocated satellite records 42-81 and then for the NMC colocated satellite records 82-121. The description given is for the NESS loop; in the NMC loop the record references 42-81 and 122-161 for NESS should be replaced by 82-121 and 162-201.

D. Go through the available satellite colocation records 42-81. For each record (containing 1-20 colocated reports) define an <u>effective time</u> equal to the mean time for all 60-byte individual reports in that record. If this time is less than t_2 it will be matched with radiosondes. (Step E). As soon as the effective time is greater than t_2 processing proceeds to step F.

E. The raob records for the 12-hrly observation times preceding and following the <u>effective time</u> of that satellite record are read in from records 2-41. The raob values of 7 layer-mean temperatures and the sea-surface temperature for the proper station are then interpolated linearly in time to the time of the individual satellite colocation. If a raob value is missing, so that this interpolation cannot be done, a raob value is produced from the other raob only if the satellite observation was within 144 minutes of the raob that is present. If all 7 interpolated raob temperatures are missing, the pair is discarded as worthless. Paired reports are also discarded if either all MSU brightness temperatures or if all retrieved temperatures are missing.

A successful pairing results in the following 30 I*2 array:

Word	
1	station number (1 - NSTN)
2	t_1 $(t = 32768*t_1 + t_2)$
3	t_2
4	e (retrieval path parameter)
5	satellite ident (e.g., 2 for NOAA-6)
6	= 0 for NESS retrieved temps.
	= 1 for NMC retrieved temps.
7-13	7 Raob layer temperatures (.1°K)
14-20	7 Retrieved layer temperatures (NESS or NMC, .1°K)
21	Sea surface temperature (.1°K)
22-29	Brightness temps. (1/64°K)
30	Unused (7777)

7777 is used for a missing value in words 7-29.

Successfully produced paired reports are accumulated in a 1200 byte record. When this is full (20 paired reports), this is written sequentially on scratch disk.

F. When all possible pair records have been written to scratch disk,† they are copied onto the regular disk at the end of the existing pair records in 122-161. If there is not enough room, the necessary number

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†4 is a typical number of new pair records from a 13 station, 2 satellite system with IEC = 200 and a 7-day update period, corresponding to 61-80 colocations/week.

of the oldest pair records (e.g., 122, 123, 124, 125) are overwritten by shifting the existing pair records in 126-161 to the appropriate earlier record location to make room for the new group of pair records at the end of the block 122-161.

Steps D, E, and F are now repeated for the NMC colocations.

G. At this point, separately for each satellite, the NESS pair records that were written to disk on the first pass through (D,E,F) for the past NUP days are read in, and the 7 retrieval temperatures are compared with the corresponding raob temperatures. Each time a difference greater than or equal to 7 degrees (in magnitude) is encountered, a diagnostic print out is triggered, so that occasions of serious radiosonde errors can be recognized (see discussion of edit cards in section 6.)† The number of NESS colocations in these recent pair records for each station is printed out, so that useless stations can be replaced by new stations if necessary (and possible).

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†During 1979, when this program was being developed, this feature served to uncover several undesirable aspects of the NMC radiosonde quality flagging procedure. These were uncovered and corrected by Automation Division personnel. One sensitive point was the hold (or keep) flag "H". This can be manually inserted by Forecast Division personnel when it is thought that a particular raob, although correct, will differ enough from the first guess analysis that analysis codes might reject the raob as probably wrong. This hold flag is most often done at the isolated maritime stations, precisely the ones that are also crucial to this colocation program. An H flag can now be inserted for more than one level (the usual practice) only for those levels that have previously passed the internal hydrostatic check in the ADP code with "A".

H. The raob records in 2-41 are rearranged. The first 2*NUP are overwritten, since their information is now contained in the new NESS and NMC pair records. The remaining raob records, up to the latest set available (these would normally amount to 2 records if the pair code ran when first called) are then moved to records 2,3,..., and the remaining records out to 41 filled with 7777 (I*2). Word 7 in the core copy of record 1 is changed to reflect this rearrangement (i.e., it is increased by 2*NUP).

I. A similar rearrangement is performed for the NESS (and NMC) satellite records 42-81 (and 82-121). Words 8 (and 9) are changed to reflect this.

J. When step I has been completed for both NESS and NMC records, the updated record 1 is written to the disk and printed out. (The details of record movement in steps H and I were also printed as they were made.)

Before stopping, the pair code prints out a statement of the number of warning messages that were printed. These could be generated as follows:

Step E. There are more than 40 pair records (NESS or NMC) to be put on the scratch sequential disk data set. (This should happen only if the code malfunctions, but is tested to avoid a system abort.)

Step G. Each time a large temperature difference is encountered in the NESS pair reports.

Step H. There are no raob records to be saved. This should never occur unless somehow the pair code is run prematurely.

Step I. There are no satellite records to be saved. (An indication that there are either no NESS or no NMC satellite colocations after the close of the update period of NUP days. This could be legitimate. For example, NMC retrieval coefficients may be lacking temporarily for both satellites, or NESS may have been unable to process many satellite reports to the NMC/EDIS disk in the past day or two.)

6. The update code

This code is submitted over the counter to perform the tasks described on page 10, after the output of the pair code has been examined for possible raob errors. This code has data cards used in steps B and E (2) below:

A. The regular disk data set is first copied onto the back-up disk (just as in the pair code). Although the update code modifies only record 1 on the regular disk, and is therefore not as subject as the pair code to embarrassment by I/O malfunction or arbitrary operator cut-off, it is possible, for example, that the most recent NESS brightness temperatures are bad, and that NMC might be informed of this only after updated coefficients using them have been put on the regular disk by the update code. The copy on the back-up disk would then enable some special <u>ad hoc</u> deletions to be made quickly to the newest pair records prior to a rerunning of the update code in this event. Other back-up requirements may also develop.

B. The GMT job initiation time is printed out. An editing step to control raob errors (if any) is performed. This uses data cards.

Data Card 1 Format I10 NEDIT

If NEDIT = 0, there are no corrections and processing goes to Step C.

If NEDIT > 0, NEDIT data cards will be read in as follows:

Data Cards 2 - (NEDIT+1) Format 5I10

The five integers on each card are

n = station number (1 - NSTN)

t_1 time = $32768*t_1 + t_2$

t_2

ℓ_1 (1 to 7) = 1st level to be edited out.

ℓ_2 (G.T.E. ℓ_1 but L.T.E. 7) = last level to be edited out.

The first three integers enable a particular 30I*2 colocation paired report to be located in the recent batch of pair records, in both the NESS group 122-161 and the NMC group 162-201. (They were printed out by the pair code when it prints out notice of a large discrepancy between (NESS) retrieved and raob layer-temperatures.)

An example of this pair code print out is given on page 38a. This example for TIROS-N occurred at ship PAPA at 0054 GCT July 31, 1980, before NMC retrieval coefficients for TIROS-N were available for the NESS operational routine NMC3PT to change third path retrievals. (The typical summer oceanic error pattern of the original NESS retrieval scheme--too warm below 700 mb, too cold above 700 mb--is very apparent, probably because this colocation, with an e value of 129, must have had a major contribution from third path (e=100) retrievals.) In this case the time consistency of the four (TAU=1153-1156) raob values for layer one is enough to show that the discrepancy is not due to a wrong raob, and therefore no editing card was prepared for this case. However, as an illustrative example, suppose the three raobs at TAU=1153,1155 and 1156 had had layer 1 values close to 290. Then the 2806 raob value for layer 1 at TAU = 1154 would have been suspicious. An examination of the raob print out from RADIO for the 0000 GMT July 31 raobs would have been necessary, together with an examination of the synoptic sea-level weather maps for the period 1200 July 30-1200 July 31, in order to judge whether the 2806 value was probably wrong or represented a real shortlived drop of 10 degrees.

This example is simple because the colocation occurred very close to 0000. An error (hypothetical) in that raob would then have had almost no influence on TIROS-N pair reports made 12 hours earlier or later. However, NOAA-6 colocations at Ship PAPA take place close to 0500 and 1730 GCT. Therefore, if the 0000 July 31 PAPA radiosonde had an error, any NOAA-6 Ship PAPA colocations in the preceding or following 12 hours might have to be edited, too—even though the discrepancy was less than 7 degrees.† The

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†The t_1 and t_2 values for the editing card would have to be hand-computed in this event from the yr, mon, day, hr, min, sec values that are printed out in place of t_1, t_2 by SATCOL. This can be done by using the (even) integer tau value TAU_o associated with the previous <u>0000</u> raob time:

$$t(\text{INTEGER}) = 43200*\text{TAU}_o + \text{SEC} + 60*(\text{MIN}+60*\text{HOUR})$$

$$t_1(\text{INTEGER}) = t/32768$$

$$t_2(\text{INTEGER}) = t - 32768*t_1$$

Sample printout by paircode of large retrieved-raob temperature difference.

(=TIROS-N)

```
*****LGE SAT-RS DIFF AT STN   1(WMC 99215), TIME  80  7 31  0 54  8(TAU=  1154.07), SAT IS NUMBER   1
                                                   THE PAIRED REPORT FLWS
     1     1521    15920    129        1        0    2806     2803     2725     2584     2433     2255     2195     2908    2820
  2699     2558     2426   2273     7777     2851   14674    16350    14924    14188    15425    14665    14572    15854    7777
                                           DIFFERENCE IN LAYERS 1-7 AS FLWS
e                                LAYER      1        2        3        4        5        6        7
        1 DENOTES SUSPICIOUS LAYER          1        0        0        0        0        0        0
                             SAT VALUS   2908     2820     2699     2552     2426     2273     7777
                            RAOB VALUS   2806     2803     2725     2584     2433     2255     2195
                                          TIME ADJACENT RAOB LYR TEMPS FOR THIS STATION
DATE= 80  7 30 12 TAU= 1153              2856     2804     2693     2555     2420     2248     2181
DATE= 80  7 31  0 TAU= 1154              2806     2804     2728     2585     2432     2256     2196
DATE= 80  7 31 12 TAU= 1155              2800     2792     2694     2570     2444     2248     2177
DATE= 80  8  1  0 TAU= 1156              2827     2811     2689     2600     2444     2256     2172
IF RAOB JUDGED WRONG, FIRST 3 OF 5 ENTRIES ON  EDITING CARD SHD BE     1    1521    15920 FLWD BY 2 LYR DIGITS
```

TAU = time in seconds from beginning of 1979 ÷ 43200.

2/day SATCOL printout of colocated satellite reports would have had to be examined in this case to see if any NOAA-6 should be edited.†

In the editing process of the NESS and NMC pair reports for station n at time t = 32768*t_1 + t_2, the raob temperatures in words 6+ℓ, $\ell = \ell_1$ thru ℓ_2, are set equal to 7777 (MSG). A record of the editing changes is printed out as they are made.

C. Retrieved temperatures in the last NUP days worth of NESS pair reports are then compared with the radiosonde values, first for satellite A and then for satellite B. Isobaric heights relative to 1000 mb are also compared with raob values. In this comparison only pair reports with e L.T.E. IEV are used.

D. Step C is repeated for the recent NMC pair reports.

E. New retrieval coefficients (10 for each of 7 layer temperatures) are now derived, for each of two satellites in turn.

(1) All NESS pair records, in 122-161, beginning with the last one and going backwards, are searched for pair reports from the proper satellite. Pair reports in which there is no raob data and/or no microwave brightness temperature are ignored. For each valid report i, sea surface temperature and 8 brightness temperatures (all in °K) are stored in an array PTOR (i,j=1,9) and the raob temperatures (in °K) are stored in an array PND (i,k=1,7). This is done until enough pair records have been examined that i reaches a value at least equal to ICOLRQ. The times of the earliest and latest pair report involved are saved. If i does not

†If this hypothetical error had existed, and it was only layer 1 of the raob that was wrong, the 4th and 5th integer on the edit card would both be 1.

equal ICOLRQ by the time all NESS pair records have been examined, the attempt to update new coefficients for this satellite is abandoned.

(2) For each layer (k=1-7), a predictor data card for this satellite is read in:

Data Card Format (11I5)

The 11 integers on a card are

1	Satellite ident number
2	Level number (should equal k)
3-11	9 values of 0 or 1 referring to the nine potential predictors in the sequence: SST, MSU(1-4), HIRS (1-3), HIRS (17). A zero indicates that that predictor is not to be used for this layer. A one indicates that it is to be used.

If the first integer does not agree with the value of ISATA or (ISATB) being used in this pass through step E, or if the second integer does not equal k, the attempt to generate coefficients in this pass through step E is abandoned; the remaining data cards are simply read in to get them out of the way, and a warning message is printed. This feature can be used to advantage if the predictor choices for this satellite are either unknown, or if known, they result in retrieved temperatures of such low quality that the NMC method should not be used. Seven blank cards should then be used in place of the normal seven data cards.

Given a valid predictor card for this layer and satellite, the raob values from PND (i,k) and the L=1-9 (L typically = 5) values of predictors from array PTOR (i,j) are put into a dense array (no msg values) PAND (i´) and PTR (i´, j´) for those values of i where the raob temperature (predictand) is present and where all needed predictors are present.

These arrays are submitted to subroutine REG, and it performs a least squares regression to derive the L+1 coefficients α_ℓ. They have the property that

$$PAND_m = \alpha_1 + \sum_{\ell=2}^{L=1} \alpha_\ell \cdot PTR(m,\ell-1)$$

$$+ \text{error}_m$$

where the mean of "error" is zero and its square has been minimized. Subroutine DGELS (dbl. prec.) is used to solve the symmetric system of linear regression equations.

(3) The statistics of this error, i.e., the success of the new coefficients on this dependent data set, are printed out, and the α's are stored in their proper location in the array

COF(10,7)

(with zero replacing the coefficient for the unused predictors). If any one layer had no data for PAND, coefficients will not be updated for any layer for this satellite. COF is converted to integer format after multiplication by 10000 and stored in the core copy KCOF (10,7,2) of record 1. The (year,mon,day) for the beginning and for the end of the colocation data base--obtained in step E(1)--are stored in words 11-16 (or 17-22) of record 1 in core.

F. The update code stops after writing the updated record 1 (containing KCOF) to the disk (and to the NESS-use set NWS.NMC.PROD.S3PRETRV) and printing out a statement of the number of warning messages. These can have occurred at the following places:

(1) In the editing process (step B), if there are no NESS or no NMC pair records as yet in records 122-161 (or 162-201).

(2) In the evaluation step C, if there are no recent NESS or NMC pair records. (This state should have been apparent from the pairing code output.)

(3) Similar to (2) in that there are no recent NESS pairs for updating coefficients in step E (1).

(4) In step D (1), there are not enough (L.T.ICOLRQ) NESS reports for one of the two satellites to justify updating the coefficients for that satellite.

(5) In step E (2), the predictor card is for the wrong satellite or wrong layer.

(6) In step E (3), one of the layers had no observations so that coefficients were not updated for that satellite. This is not likely to happen unless ICOLRQ is set very small (e.g., 10). The raob reports put into records 2-41 by RADIO in the 2/day program are not always complete because some geopotential heights have not received an A or H flag in the NMC automatic processing system.†

After the over/counter update code has run successfully, a second over/counter job should be submitted to copy the 229 records to the back-up disk. This will record the updated retrieval coefficients on the latter, in case the regular disk gets corrupted before the next pair code.

†The number ICOLRQ only sets a necessary lower limit on the paired reports accumulated in the arrays PND and PTOR by the update code. Each individual layer will usually have a slightly smaller value. For example, on Aug. 5, 1980, 105 valid pairs (for NOAA-6) were put into PND and PTOR (ICOLRQ was 100), but the seven layers had respectively only 80, 93, 92, 94, 96, 95, and 90 reports in PAND and PTR. The NOAA-6 colocation data base had 13 stations and extended from July 21 through August 2.